Nanoscale Spatial Structure of High-T_C Vortex Core

J. C. Séamus Davis, **University of California, Berkeley. DMR 9971502**

***Science 266*, 455 (2002).**

Scanning tunneling microscopy is used to image the additional quasiparticle states generated by quantized vortices in the high-Tc superconductor Bi2Sr2CaCu2O8+δ. They exhibit a Cu-O bond oriented 'checkerboard' pattern, with four unit cell ($4a_0$) periodicity and a ~30Å decay length. This discovery is important for several reasons. First, the $4a_0$ periodicity and register to the Cu-O bond directions of the vortex-induced LDOS are likely signatures of strong electronic correlations in the underlying lattice. Such a $4a_0$ periodicity in the electronic structure is a frequent prediction of coupled spin-charge order theories, e.g. STRIPES, but has not been previously observed in the quasiparticle spectrum of any HTSC system. Second, the relatively large size of the vortex 'halo' (10 nm radius) is important to the understanding of several other recent discoveries including the inelastic neutron scattering results and the Nernst Effect.

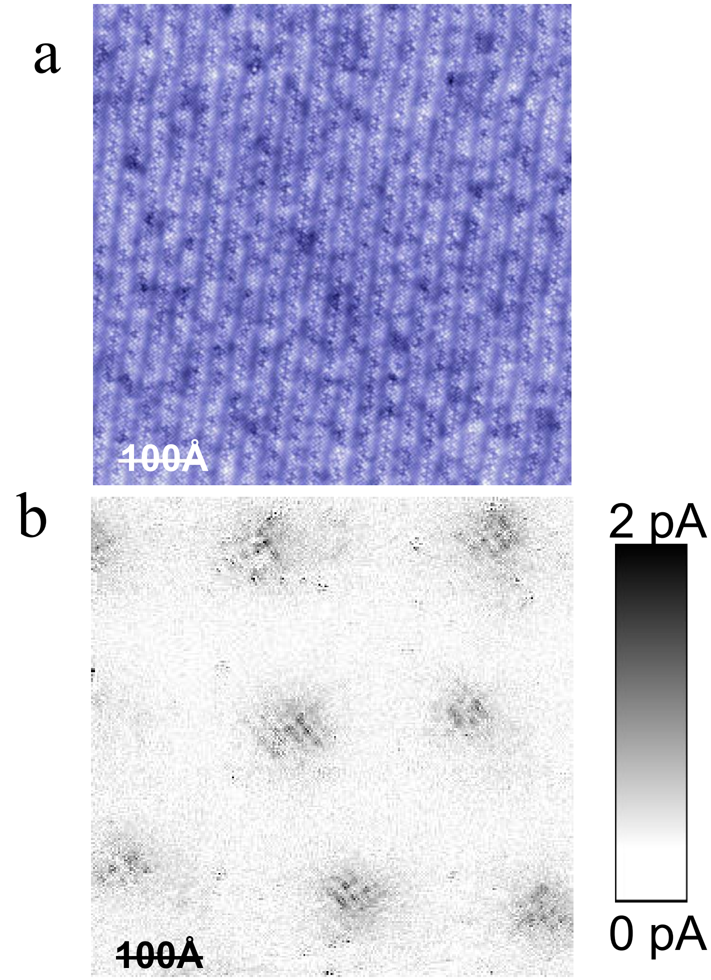

Figure Caption. Topographic and spectroscopic images of the same area of a Bi-2212 surface. (a) A topographic image of the 560Å field of view (FOV) in which the vortex studies were carried out. (b) A map of showing the additional LDOS induced by the 7 vortices. Each vortex is apparent as a 'checkerboard' at 45° to the page orientation.

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Brief summary of outreach activities:

- Maintained Website for public access to research program
  http://ist-socrates.berkeley.edu/~davisgrp/jcdavispubs.htm
- PI gave 27 public lectures on results of research program.
- Regular visits to Davis-lab by high school students, college students from other campuses, and scientists from around the world.
- Numerous interviews with science press and yielding several prominent stories including:

"Magnetism and Superconductivity fight for control in High-Tc superconductors" B. Levi, **Physics Today 55**, 14, 2002.

"Tuning order in cuprate superconductors" S. Sachdev and S-C Zhang, **SCIENCE 295** , 452, 2002.

"A star role for stripes", J. Tranquada, **Physics World**, June 2002.

Educational:

1 undergraduate

4 grad students (1 supported by DMR 9971502)

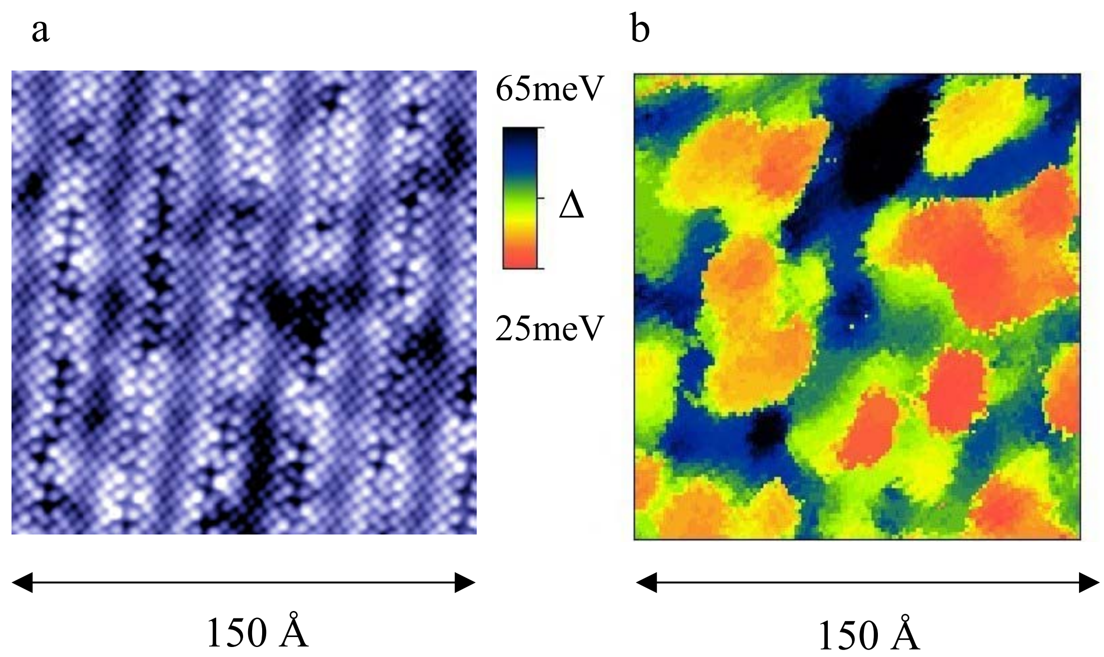
6 post-docs.

Nanoscale Electronic Phase Separation in the Cuprates

J. C. Séamus Davis, **University of California, Berkeley. DMR 9971502**

Nature 413, 282 (2001)
Nature 415, 412 (2002)

Granular superconductivity occurs when microscopic superconducting grains are separated by non-superconducting regions through which they communicate by Josephson tunneling. Although crystals of the cuprate high-T_c superconductors are not granular in a structural sense, theory has long predicted that the holes can become concentrated at some locations resulting in hole-rich superconducting domains. Granular superconductivity due to Josephson tunneling through 'undoped' regions between such domains represents a new paradigm for the underdoped cuprates. We carried out studies of the spatial interrelationships between STM tunneling spectra in underdoped $Bi_2Sr_2CaCu_2O_{8+\delta}$. We discovered an apparent spatial segregation of the electronic structure into ~3nm diameter domains (with superconducting characteristics and local energy gap Δ<50 meV) in an electronically distinct background. These observations suggest that underdoped $Bi_2Sr_2CaCu_2O_{8+\delta}$ is a mixture of two different short-range electronic orders with the long-range characteristics of a granular superconductor.



a. Topographic STM image showing locations of each individual atom on the BiO surface of BSCCO. b. High spatial resolution STS data from same location showing the spatial distribution of superconducting energy gap Δ and revealing approximately 12 superconducting domains (orange/red) embedded in the percolative background of a different electronic structure (blue/black) .

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  "High Temperature Superconductivity: Quantum salad Dressing" J. Zaanen, **Nature 415**, 379 (2002).

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1 undergraduate
4 grad students (1 supported by DMR 9971502)
6 post-docs.